ESSAY

ON THE

USE OF LIME AS A MANURE,

Marc Antoine

BY M. PUVIS.

TRANSLATED FROM THE FRENCH

BY

E. RUFFIN, ESQ. *Editor of the Farmer's Register.*

WITH AN

INTRODUCTION,

EXPLANATORY OF THE PRINCIPLES OF AGRICULTURAL CHEMISTRY,

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ON THE USE OF LIME AS A MANURE.

BY M. PUVIS.

EDITOR'S PREFACE.

The task of adapting an Introduction explanatory of the chemical principles most important in agriculture to the Essay of Mr. Puvis, was undertaken at the instance of a valued friend, James Wadsworth, Esq. of Geneseo. The translation which is employed was liberally placed at my disposal by the very intelligent and practically skilful editor of the Farmer's Register. He has the merit of first bringing the Essay of Mr. Puvis before the American public, and, taken in connexion with his own Essay on Calcareous Manures, he has thus made us acquainted not only with all that was previously known in the theory or practice of the use of Lime in agriculture, but has added himself some most valuable theoretic views, which he has also established by successful and judicious experiments on his own farm.

James Renwick.

Columbia College, March, 1836.

PREFACE

OF THE TRANSLATOR.

The publication of the following communication to the *Annales de l'Agriculture Francaise*, was commenced in the February No. of that journal, (which was received here in May,) and the June No. contains the end of the first part, "*On Liming*," and enables us to offer the translation of that portion to our readers. Only a few pages of the next portion of the series, "*On Marling*," has yet appeared, and not enough to permit a judgment to be formed of its worth.

Though there are many deficiencies in this treatise on liming—and also opinions as to the theory of the action of lime, in which we cannot coincide—still, on the whole, we consider it as presenting far more correct views, and more satisfactory information, both on theory and practice, than any other work on liming that we have before seen. In other points, and those of most importance, the facts here presented (and now first learned from any European authority) strongly sustain the views maintained in the *Essay on Calcareous Manures*. It would be both unnecessary and obtrusive to remind the reader of these points of difference, and of agreement, whenever passages exhibiting either may occur. They will, therefore, generally be submitted in the author's words without comment. A few exceptions only to this rule will be made, in cases which appear particularly to call for them.

We have no information whatever of Mr. Puvis, the author of this treatise, previous to the appearance of the commencement of the publication in the *Annales*. But he is evidently well informed on his subject, and is stated by the introductory remarks of the French editor, to be entitled to all respect, for his long experience, and his practical as well as scientific investigation of the subject. If, then, there remains no ground to distrust his judgment or his facts, the statements made are most important to a very large portion of this country, which has heretofore been generally supposed to be deprived of all possible benefit from the use of calcareous manures on account of their remoteness and high price of carriage. M. Puvis states that the most successful and profitable liming in Europe (for the expense incurred) is in repeated applications of very small dressings—making less, on the average, than four bushels of lime to the acre, annually. This small amount, *if really as efficacious as is alleged*, would cost so little in labor and money, that the limits of the region capable of being limed may be very far extended. It would not matter though the applications should require to be repeated for ever, provided the annual returns gave good profit upon the annual expenses; and far greater will be the profit, if (as we think) the soil ultimately will no longer require such repetitions—or only at very distant intervals of time—and still be a highly productive, because it has been made a calcareous and fertile soil.

INTRODUCTION.

THE Chemical facts and principles which are applicable to Agriculture are neither numerous nor complex. They are, however, to be found only in works on General Chemistry, in which they are intimately associated with laws and phenomena of a more abstruse description, and in connexion with which they constitute a science of which the most learned are still students, and to attain which in its existing form may require years of close and attentive study. The language, too, of Chemistry, which, to those who study it in a regular course, serves as an artificial memory, and single words of which call up long trains of thought and experiment, presents to the uninitiated all the difficulties of a foreign tongue.

Yet it cannot be doubted, that the practical farmer may derive important benefit from acquiring so much of this language as will enable him to understand the chemical explanation of the numerous changes which are continually taking place in the natural actions which it is his high privilege to call into his service, to direct in part, and modify in degree. So also are there certain chemical elements and compounds, with the properties of which he ought to be acquainted if he wish to be able to direct his practical skill with more effect, even in circumstances familiar to him, but which may be absolutely necessary, or will at any rate save waste of labour and loss of time, when the knowledge acquired by practice in one place is to be employed in a new situation, and under a change of circumstances.

It is the object of this introduction to exhibit, in such form as may be intelligible to those who have not made general chemistry an object of study, a concise view of such of the laws and facts of that science, as are absolutely necessary for the agriculturist who may wish to improve his practice, and which are more particularly required by those who wish to avail themselves of the knowledge contained in the subjoined essay. To do this has been found no easy task. It would be in itself difficult, but to the author of this introduction has been more particularly so, as he has for years been in the habit of imparting instruction to those whose habits of life and thoughts are as remote as possible from those of the practical farmer; persons to whom the peculiar language of chemistry is an aid instead of an impediment; and who, with ample time at their command, have an opportunity of pursuing the study of the science step by step. Fully aware of these difficulties, both general and peculiar, this attempt would not have been made, and certainly not persisted in, had it not have been for the instances of an intelligent, scientific, and successful farmer, who has urged the completion of the task as an object likely to be beneficial to those, who, with perhaps equal zeal and native powers of mind, have not enjoyed, like himself, the advantages of a scientific education.

The atmosphere which surrounds our earth is the first object to which our attention should be directed. This is the vehicle of the moisture, which, whether it fall in the form of rain or dew, run in streams or issue from springs, is absolutely essential to the success of the farmer's labour. It is also, as we shall presently see, important to him on other accounts.

The greater part of the atmosphere is made up of a mixture of substances, each of which has the same mechanical properties as the whole mass. These air-like substances are known to chemists by the name of *Gases*.

Of these gases, two make up by far the greater portion of atmospheric air, and exist in it in the proportion of about four to one. That which is the largest in quantity and makes up nearly 4-5ths of the whole atmosphere, is called, in the Essay of M. Puvis, by the name of Azot, but is more usually known in English by the name of Nitrogen.

This substance, although in the largest proportion, is the least important of the gases in its chemical effects. It does not aid in supporting the life of animals, nor in maintaining the burning (*combustion*) of inflammable bodies.

The part of the atmosphere which is absolutely necessary for these purposes, is called by the name of *oxygen*, and nearly makes up the remaining fifth part of atmospheric air. In its support of life it always, and in maintaining combustion often, unites with a chemical element, which is called *carbon*. This is familiarly known as forming the principal part of charcoal. In its union with carbon,

oxygen forms a peculiar gas known by the name of carbonic acid.

Carbonic acid is always found in small quantities in the atmosphere, to which it is furnished by the breath of animals and the fumes of burning bodies. It is, when in considerable quantities, fatal to the life of animals, but is prevented from accumulating to an injurious extent in consequence of its being taken up by water; it is therefore dissolved, in proportions about equal to those in which it is formed, by rivers, lakes, the ocean, and the moisture of the soil.

Water exists in the atmosphere in the form of vapour. The great source of this vapour is the extended surface of the ocean; and it is governed by a mechanical law, by which it is continually tending to distribute itself uniformly over the whole surface of the earth. It may thus exist in as large quantities over the surface of the dryest land as over that of the ocean itself. This tendency to equal distribution is continually counteracted by the changes in the sensible heat (*temperature*) of the atmosphere, and of the surface of the earth, which follow the alternations of day and night, and the vicissitudes of the seasons. By these alternations and changes, the vapour is caused to fall (*precipitated*) in the form of rain, snow, hail, dew, or white frost, according to circumstances. As such changes of temperature are more frequent on the land than on the ocean, the water which falls on the former in either of these forms is greater in quantity than that which falls on equal surfaces of the latter. Thus, by a wise and benevolent provision of Providence, the water of the ocean is continually furnishing vapour, which is precipitated on the land for the support of vegetation and the supply of springs, and whose excess is poured back into the ocean in streams and rivers.

Water has been found by chemists to be a compound substance, made up of two elements. One of these, which forms 8-9ths of its weight, is the gas already mentioned under the name of oxygen; the other, a peculiar gas, known by the name of *hydrogen.*

Hydrogen, when free, is the lightest of all known bodies, rising and floating in atmospheric air; it not only combines with oxygen, to form water, but with carbon to form a great variety of compouuds—gaseous, liquid, viscid, and solid. It also combines with nitrogen, and forms a gas known by the name of ammonia, which is well known by the peculiar smell it gives to spirits of hartshorn (*liquid ammonia*).

Hydrogen also combines with sulphur, forming a gas known by the name of sulphuretted hydrogen; this exists in the atmosphere, but in such small quantities as only to be detected by the nicest chemical tests. It combines in like manner with phosphorus, forming phosphuretted hydrogen gas, whose presence in the air is occasionally perceptible.

Oxygen, as we have seen, unites with carbon, to form a gas which we have called carbonic acid.

This receives the latter part of its name from its similarity in properties to an extensive class of compound bodies, known by the name of *The Acids.* The greater part of these, like carbonic acid, are combinations of inflammable bodies with oxygen. The most important of these in reference to our present object, are the sulphuric and phosphoric acids; named from the two substances (sulphur and phosphorus) which are their bases. Muriatic acid may also be mentioned here, although its composition is of a different character. Oxygen unites with other bodies to form a class of compounds known under the name of oxides.

The acids unite with earths, alkalis, and metallic oxides, to form a class of compounds known under the general name of salts. These are named from the two substances which enter into their composition: thus, the salt formed of sulphuric acid and the earth lime, is called sulphate of lime. The substances which unite with acids to form salts, are called the *bases* of the respective salts.

Of these bases, the alkalis and earths are the most important. Of the alkalis, it is only necessary to know the names of two, namely *potassa* and *soda*, and to be aware that their distinctive properties, are: to possess an acrid taste, a caustic operation, to render oils capable of mixing with water, and to neutralize the properties of acids.

The earth which chemists call by the name of silex or *silica*, is found almost pure in flint and rock crystal; it is also almost pure in sharp colourless sands, and is by far the larger part of sands of every description. So far as the farmer need know its properties: it is hard, rough to the touch, has no attraction for water, which it permits to filter through, or evaporate from it, with the greatest ease. It is capable of uniting with the other earths in compounds which are called silicates, and is the only earth which enters into the formation of soils uncombined with the others or with other elements.

The earth which chemists call by the name of *alumina*, is so named because it is obtained by them in a pure form from the well-known salt called alum, of which it is the basis. Its most marked characteristic is plasticity: that is to say, it may be formed into a paste with water, will then easily receive any form

which may be given it, and retain that form unaltered, even by violent heat. It never exists in soils unmixed, but in intimate association, or more probably chemical combination with silica, it is the well-known substance called clay, or argillaceous earth. White clays are this combination nearly pure, and coloured clays often contain it with no other addition than metallic colouring matter. Clay retains the plastic property of alumina; it therefore causes soils to be retentive of moisture; and, when they dry, makes them form tough clods or crusts, similar in character to sun-dried brick.

Soils which contain clay are often also mixed with sand, or with an excess of silica in grains, which does not enter into the composition of the clay. Such a soil is less liable to form a tough crust than a pure clay, but it will require a very large proportion of sand to destroy this property altogether.

Clay mixed with sandy soils renders them more retentive of moisture. Sand and clay have therefore been used as manures for each other; but it may reasonably be doubted whether all the advantage that has been anticipated by some from this process, can be realized, as such a mixture will be merely mechanical.

Loamy soils are generally said to be mixtures of sand and clay; they undoubtedly usually contain both these earths, and even sometimes a large excess of sand. But we shall give reasons for believing that loams owe their peculiar value to a combination of clay with another substance, by which a change is produced in its chemical characters.

Lime is familiarly known to farmers by the same name that is generally used by chemists. It is obtained by the aid of heat from rocks which go by the name of limestones. These are combinations of lime with carbonic acid, which is fixed in them by chemical attraction, but which, when driven off by heat, takes the same form as the air of the atmosphere, or becomes a gas. This gas from this circumstance has been called *fixed air*, by which name it is often known when causing the sparkling and froth of cider and beer. The principal part of limestone is therefore called by chemists *carbonate of lime.* Carbonate of lime is also found in shells, both those of living animals and those which exist in the ground in a fossil state. In the former it is mixed with animal matter, which is more or less separated from the latter according to the time which has elapsed since the death of the shell fish.

Marl, in the sense in which the term is used by chemists, is a mixture of clay with carbonate of lime. The English writers on agriculture have not observed this distinction, and the term is sometimes applied by them to a decomposed chalk, which may contain little or no clay; and sometimes to clay which contains no carbonate of lime. In fact, the name is frequently applied by them to any earthy matter found below the vegetable soil, which is capable of increasing its fertility. From this misapprehension, the substances which go by the name of marl in New Jersey, Maryland, and Virginia do not correspond with the chemical definition, but are generally beds of fossil shells mixed in various proportions with earthy and saline matters of various kinds.

Lime is a substance very different in its characters from the two earths of which we have previously spoken. When prepared by heat from any of the original forms of its carbonate, it retains their shape unaltered, but may have its colour changed, and always loses considerably in weight. It is now acrid, caustic, and corrosive, and has some properties in common with potash, which are therefore alkaline. Of these the most important is, that it unites with acids to form compounds included in the general class of salts. Of the salts of lime which are important to the farmer, the three principal are: the *carbonate*, which, as we have stated, is found in limestone, chalk, shells, and marl; the *sulphate*, in which lime is combined with sulphuric acid, and which in combination with water is the substance so well known to our farmers under the name of plaster of Paris, or less familiarly by that of gypsum; the *phosphate*, which constitutes a large part of the bones of animals.

Lime, when exposed to the air, attracts carbonic acid, which is always to be found in the atmosphere; it thus passes back to the state of carbonate, but in so doing gradually falls to powder, and is then said to be *air-slaked.* If slaked with water, it also falls to a powder, which still retains the caustic character of the burnt lime; but this powder, when exposed to the air, unites with carbonic acid more rapidly than when in mass.

Lime, in its caustic state, has the property of rapidly decomposing vegetable and animal substances, thus hastening the natural processes by which they are finally destroyed; or, to speak more properly, have their elements resolved into new combinations. The offensive and unwholesome gases, which are given out by this composition, are absorbed by the lime, and prevented from mixing with the air. The same property is possessed in a less degree by the carbonate of lime, and probably by its other compounds; but in order that either this earth or its compounds shall

manifest this property, they must be in small fragments, or, which is better, in fine powder.

Wet sand and plastic clay, and those soils to which they give their characters, also possess the property of absorbing gases ; but they have this in a very inferior degiee to lime and its compounds. As the gases generated by the decomposition of vegetable and animal substances form a large part of the necessary food of plants, it is obvious that a soil which contains the carbonate of lime, may retain and store them up for use, while they will be lost in soils of a different character.

Carbonate of lime may also be made a most important article in the preservation of the most valuable parts of putrescent manures, until they can be applied to the soil. In this way marl is applied to a great extent in China ; the night soil of their numerous population is there formed into cakes like bricks, with marl, and thus loses its offensive smell ; but when these are applied as manure to the land, they give out the gases again as they are required for the nourishment of plants. So also in Norfolk, the site for dunghills is prepared by a layer of marl, which is incorporated with the manure from time to time, and retains the gases which would otherwise be lost.

Lime may therefore be applied in its caustic form in some cases in Agriculture, for it will hasten the decomposition of animal and vegetable matters which might otherwise be inert ; it will also neutralize acids, which experienced farmers well know to exist in many soils, which they in consequence call sour. But the latter purpose will be answered as well by the carbonate of lime, which may be applied as it exists in marl or shells, or as it may be prepared by grinding limestone. Caustic lime is also dangerous in its application, for it will corrode and destroy living vegetables, and hasten the decomposition of the vegetable matter of the soil to such a degree as to injure its fertility. Except upon turf-bogs, and land loaded with timber not wholly decomposed, quick or caustic lime ought not to be used ; but to burn lime, and then by slaking to reduce it to the form of fine powder, which is speedily carbonated by exposure to the air, is a more ready, and generally a cheaper mode of obtaining the carbonate in a convenient form, than to grind limestone to powder in mills. Yet for many of the most valuable uses of lime in agriculture, the latter method, if as cheap, would answer as well.

Lime slowly combines with the earth silica, and produces a compound very different in character from either. It is this, to cite a fact in proof of our statement, which gives the hardness and solidity to ancient mortar. The carbonate of lime will serve to form this compound ; and thus, when it has had time to act upon sand, it renders a silicious soil more retentive of moisture ; while, if applied to clay, by combining with its silicious matter, it renders it more friable ; and it is to the formation of this compound by slow degrees, that we are inclined to ascribe the valuable mechanical properties of loamy soils, and the gradual amelioration produced by the use of lime, marl, and shells as a manure.

Besides silica, alumina, and lime, an earth called magnesia is likewise found in some soils. It is also, in the form of carbonate, a frequent constituent of limestones. This earth has many properties in common with lime ; like lime it is capable of neutralizing acids ; and when deprived of carbonic acid by heat, corrodes vegetable substances. It probably also hastens putrefaction, and both it and its carbonate are capable of absorbing the gases let loose in that natural process. It is, however, of little interest in agriculture, except as a part of some of the limestones which are used as manure. These, if applied in large quantities, are sometimes very injurious to vegetation ; the reason of this is, that magnesia does not repass to the state of carbonate as rapidly as lime, and therefore retains its corrosive quality long after the lime has again become mild by its union with carbonic acid. In less quantities, however, the magnesian limestones may serve as a manure, but their application requires great caution, particularly when the quantity of magnesia amounts to 25 per cent.

All of the simple substances we have mentioned, except perhaps the last, either separate or in various states of combination, exist in plants. The manner and character of the combination is influenced by the vital action of the plant, which causes them to form compounds, often in direct opposition to th manner in which the ordinary laws of chemistry would direct. It thus happens that so soon as the plant ceases to live, these chemical laws, being no longer impeded, begin to exert their influence ; and if it be in such a state as will admit of the several elements acting readily upon each other, a decomposition, more or less rapid, of the vegetable structure ensues. It is a law of chemistry, that its action is always aided by the bodies being in a fluid state, and the action is often impossible when the bodies are perfectly free from moisture. Hence the direct chemical action, and consequent decomposition, takes place with greater certainty and more rapidi-

ty in green juicy and succulent vegetables, than upon those which have been deprived of moisture either naturally or artificially. Thus grass, if heaped up in a recent state, decomposes, and if but partially dried, is heated, and may even take fire, by the chemical action of its elements; while, if dried by exposure to the sun and air, and then laid up in a dry place in the form of hay, it is almost indestructible. A moderate degree of heat and access to air are also necessary to promote the chemical action by which decomposition is effected. This decomposition is often attended with motion among the parts; and always, if the mass has a liquid form, as in the expressed juice of vegetables, or in the steeps employed by distillers and brewers; it goes in general terms by the name of fermentation. When the vegetable matter abounds in starch, the first change is the conversion of this principle into sugar. Sugar, if thus formed, is next converted into alcohol, as it is, if it previously existed in the plant. The presence of alcohol gives the liquid in which it exists the character of vinous liquors, and if these are permitted to remain in a turbid state, a farther fermentation converts them into vinegar; and finally vinegar is farther decomposed, and the vegetable matter, giving out an offensive smell, is said to putrify. If the substance be not an expressed juice or liquid steep, these several stages of fermentation ensue with rapidity, may be going on at the same time, and are sometimes so speedy in their course that no other action but the putrefactive fermentation can be detected. Animal bodies are subject to the same laws, and go through the same stages of fermentation, but the rapidity which they run into putrefaction is even greater; still there are some cases, as in that of milk, where the vinous stage can be occasionally, and the acetic distinctly, observed. Thus, a vinous liquor is prepared in some countries from milk, and the sour taste which appears in it when kept, arises from the presence of vinegar.

In the several stages of fermentation, parts of the vegetable assume the form of gas or vapour, and are given out to the air. The gases which have been detected, are carbonic acid, a gaseous compound of carbon and hydrogen, and in some instances ammonia. The vapour is that of water, which escapes in greater quantities than it would under ordinary circumstances, in consequence of the heat with which the process is attended. If exposed to rain, soluble salts, with earthy and alkaline bases, are washed from the mass. Finally, a mass of earthy consistence alone remains, which on examination is found to be made up of earths, insoluble salts, and carbon, being, in fact, identical with vegetable mould.

We may hence infer that the following elements exist in vegetable bodies:

1. Oxygen, developed in the carbonic acid and water.
2. Hydrogen is in the water and carburets of hydrogen.
3. Carbon.
4. Earths.
5. Alkalis.
6. Nitrogen, occasionally developed in the form of ammonia.
7. Acids, remaining in the insoluble, or washed away in the soluble salts.

The chemical examination of vegetable bodies ought of course lead to similar results. This examination has been conducted in three different ways.

1. With the view of discovering the nature of the compounds, called vegetable principles, which exist ready formed in plants.
2. For the purpose of discovering the chemical elements contained in these principles.
3. By the destructive action of heat, under which some of the elements are wholly separated, and others enter into new combinations.

In the first of these methods there have been detected:

I. Certain peculiar acids, of which we may cite
   (1) Acetic acid, which, mixed with water, forms common vinegar;
   (2) Citric acid, which is found in the lemon and orange.
   (3) Malic acid, which exists in the apple;
   (4) Tartaric acid, in the juice of the grape;
   (5) Oxalic acid in the wild sorrel.

II. Certain substances of alkaline character, found principally in medicinal plants, to which they give their peculiar virtues.

III. Gum, resin, oils, sugar, starch, and two substances approaching to animal matter in their characters, namely, albumen and gluten; the former of these has a resemblance to the white of eggs, the latter to animal jelly or glue.

Many other principles are separated by the same method in different plants, but need not be enumerated by us.

The basis of this method consists in acting upon vegetables by water, ether, or rectified spirits (alcohol), and the principles above enumerated are either simply, or in the state of combination in which they exist in plants,

soluble in at least one of the liquids we have named.

In all cases some insoluble matter is left, and this is known by the name of the woody fibre.

When these principles are treated by the second method, oxygen, hydrogen, and carbon, are the uniform results, but in different proportions in the different cases; nitrogen is also detected in some of them, as, for instance, in the alkaline principles and in gluten. This method does not appear to be adequate to determine whether earths and alkalis are, or are not, parts of these vegetable principles. From the very remarkable fact, that some of those substances, which are very dissimilar to each other, yield exactly the same proportions of oxygen, hydrogen, and carbon, we may fairly conclude by chemical analogy, that one or the other, or perhaps both, contain some substances which have escaped the analysis. As an instance we may cite starch and sugar, whose characters are so dissimilar that no danger can exist of mistaking the one for the other; and yet their analysis by the second method gives identical results.

The third method may be understood by comparing it with the process used in making charcoal. If this be so far altered that the heat employed shall not arise from the combustion of a part of the substance to be examined, but from one merely used as fuel, and if the matters which escape in smoke are condensed and collected, we shall have that employed occasionally on a large scale by operative chemists. In this way charcoal will be, as usual, obtained in the solid form. The condensible products will be water, tar, turpentine, or resin; and the acid which gives that character to vinegar, but which in the present case, in union with the tar and water, is called pyrolignous acid.

If the charcoal be burnt in a current of air, all its carbon is converted, by union with the oxygen of the atmosphere, into carbonic acid, leaving a residue familiarly known as ashes. The ashes are made up partly of soluble and partly of insoluble matter. The soluble matter is separated by the familiar process of making ley, and the ley, if evaporated, leaves the solid substance so well known as potash.

Potash is principally composed of a carbonate of potassa, but contains, besides silica, rendered soluble by the alkali, sulphate and muriate of potassa, and a peculiar acid known by the name of ulmic, which is a compound of carbon, hydrogen, and oxygen. The insoluble part is made up of carbonate of lime, sulphate and sometimes phosphate of lime, silica. The carbonate of lime has probably in no case existed in the living plant, but arises from the destruction by heat of the peculiar acid of the plant; as, for instance, the citric, the oxalic, or the tartaric; all of which are by fire converted into carbonic acid.

The quantity of ashes is extremely various, as is their proportion of the several soluble and insoluble substances, we have mentioned. Thus the ashes of the stalk of Indian corn yields 12½ per cent. of ashes, while the soft woods do not furnish more than two parts in a thousand. The proportion of the sulphate and phosphate of lime is even more various. Thus, in some cases the presence of the sulphate is hardly perceptible, while of the ashes of clover it forms a large proportion of the whole weight. Phosphate of lime is found in the proportion of fifteen per cent. in the grain of wheat.

Water is not only one of the principal component parts of all plants, but is also the sole vehicle of their nutriment. At each extremity of the small fibres into which the roots of plants are divided, is an opening through which that fluid enters; and it appears that, except in the case of a plant having lost its vigour by continued drought, it is only through this channel that water can enter. By a powerful action inherent in living vegetables, water, which with all the matters it is capable of holding in solution, becomes the sap,* is raised to the highest parts of the plants, and forced to their most distant extremities. It has been ascertained that plants do not possess the power of rejecting even those substances which are most noxious to them; it is therefore probable that the character of the fluid admitted is the same in all the plants which grow upon the same soil. Whether it undergoes any change in the root does not appear certain, but it has recently been maintained that every description of plant throws off by the surface of its roots such matter as, if retained, would be injurious; but this opinion does not appear to be well established.

The sap, when carried up to the leaves, undergoes an important change, principally owing to the action of solar light. When exposed to light, the leaves of plants give out oxygen in considerable quantities. This proceeds from a decomposition of the water and carbonic acid, the remaining elements of which two substances and a portion of their oxygen enter into new combinations. These combinations have different characters in different vegetables, but are most familiarly known in the shape of gum and resin. These still contain the earthy and saline matter carried

* See Roget's Bridgewater Treatise.

up by the sap, and after they are formed return downwards towards the roots. In their descent they deposit the several parts which minister to the growth of the plant—the leaves, the bark, and the woody fibre. They also appear to be forced with powerful energy into the flower and the growing fruit, and in these a still more important action is carried forward, by which the reproduction of the species is ensured.

The matters which the water that enters by the root may hold in solution, are either derived from the atmosphere or from the soil. In its passage through the air it will carry with it a considerable proportion of carbonic acid, and all the sulphuretted hydrogen it meets with. It will also take up a small quantity of oxygen, and of carburetted hydrogen, and a still less quantity of nitrogen. From the soil it will take all the more soluble salts, small quantities of sulphate, phosphate, and carbonate of lime, provided they be present, and silica. So also if the soil contain animal matter, or vegetables of which nitrogen forms a part, the ammonia generated by their decomposition will likewise be dissolved by the water. In like manner the carbonic acid, which has arisen from the decomposition of vegetable or animal matter, and has not yet escaped, and the soluble compounds of carbon, oxygen, and hydrogen, which are generated by the same process, will have been taken up, and carried by the water into the root of the plant. It will thus appear that, contrary to the opinion of Mr. Puvis, the atmosphere furnishes but little of the fixed elements of plants, with the exception of sulphur and carbon; and that even if the growth of plants were to depend wholly upon the carbon obtained in the form of carbonic acid from the atmosphere, their growth must be slow and feeble. It will also appear, that if lime do not exist in the soil, but few plants can find nourishment; and that for the ripening of the seeds of grain phosphorus must be furnished also. The latter substance may be absorbed in small quantities from the phosphuretted hydrogen, which is occasionally present in the atmosphere; but a more certain supply ought to be sought in putrescent manure, and particularly in that of animal origin.

The uses of lime in agriculture, as will appear from the foregoing remarks and the reasoning of the essay, are as follows:

1. When a soil contains inert animal or vegetable matter, their decomposition may be promoted, and it may be rendered fit for the food of plants, by the addition of caustic lime.

2. If the soil contain acid, that may be neutralized either by caustic or carbonated lime, and besides, the organic matter whose decomposition may have been prevented by the acid, will be permitted to putrify.

3. Soils containing too much silica, or in other words those which are sandy, are made more retentive of moisture by the addition of lime or its carbonate.

4. Clays, may be rendered less retentive of moisture, and more friable by the same means.

5. The gases which escape when vegetable or animal matter putrify, are retained in the soil by means of lime or its carbonate; and thus a given quanity of manure, or the original vegetable matter of the soil, will retain its efficacy longer. By a recent discovery, it has also been ascertained that the decomposition of plants yields a peculiar acid, called the humic, which forms with lime a salt sparingly soluble in water. The generation of this salt also serves to render the neutriment contained in the soil more lasting.

6. Lime and its compounds are absolutely necessary, as constituent parts, to the growth of many plants. The sulphate is essential to the growth of clover, and the phosphate to that of wheat. Hence the efficacy of plaster of Paris and crushed bones as manures.

7. If lime or its sulphate be employed as the means of raising green crops, which have but small exhausting powers, the fertility of a soil may be maintained by ploughing them in, or increased by using them to feed cattle whose manure is applied to the ground.

ON THE USE OF LIME AS A MANURE, BY MR. PUVIS.

On the Different Modes of Improving the Soil.

To improve the soil is to modify its composition in such manner as to render it more fertile.

This definition, which might be extended to manures charged with vegetable mould [*humus*] or animal substances, which also modify the composition of the soil, is limited by French agriculture to substances which act upon the soil, or upon plants, without containing any notable proportion of animal or vegetable matter.

It is said that manures, [putrescent or enriching,] serve for the nutriment of plants. But it is the same as to substances improving to the soil, which furnish to it matters which it needs to be fruitful, and which furnish to vegetables, the earth and saline compounds which enter as essential elements in their composition, their texture, and their products. Such improving substances may well be regarded as nutritive.*

Thus lime, marl, and all the calcareous compounds employed in agriculture, since they furnish lime and its compounds, which sometimes form half of the fixed principles of vegetables, ought also to be considered as aliments; or, what comes to the same, as furnishing a part of the substance of vegetables. Thus again, wood-ashes, pounded bones, burnt bones, which furnish to vegetation the calcareous and saline phosphates which compose a sixth of the fixed principles of the stalks, and three-fourths of their seeds, ought well to be considered, and surely are, nutritive.

What, then, particularly marks the distinction between manures which improve the soil [*amendemens*] and alimentary manures, [*engrais*] is, that the former furnish, for the greater part, the fixed principles of vegetables, the earths, and salts, which are abundantly diffused throughout the atmosphere, whence vegetables draw them, by means of suitable organs; and what is most remarkable, is, that the vegetable, by receiving the fixed principles of which it has need, acquires, as we shall see, a greater energy to gather for its sustenance the volatile principles which the atmosphere contains.

The greater part, then, of soils, to be carried to the highest rate of productiveness, require manures to improve their constitution. Alimentary manures give much vigor to the leafy products—but they multiply weeds, both by favoring their growth and conveying their seeds; and they often cause crops of [small grain] to be lodged, when they are heavy. Manures which improve the soil, more particularly aid the formation of the seeds, give more solidity to the stalks, and prevent the falling of the plants. But it is in the simultaneous employment of these two means of fertilization by which we give to the soil all the active power of which it is susceptible. They are necessary to each other, doubling their action reciprocally; and whenever they are employed together, fertility goes on without ceasing; increasing instead of diminishing.

The greater part of improving substances are calcareous compounds. Their effect is decided upon all soils which do not contain lime, and we shall see that three-fourths, perhaps, of the lands of France are in that state. Soils not calcareous, whatever may be their culture, and whatever may be the quantity of manure lavished on them, are not suitable for all products; are often cold and moist, and are covered with weeds. Calcareous manures, by giving the lime which is wanting in such soils, complete their advantages, render the tillage more easy, destroy weeds, and fit the soil for all products.

Improving substances have been called *stimulants;* they have been thus designated, because it was believed that their effect consisted only in stimulating the soil and the plants. This designation is faulty, because it would place these substances in a false point of view. It would make it seem that they brought nothing to the soil nor to plants; and yet their principal effect is to give both principles which are wanting. Thus the main effect of calcareous manures proceeds from their giving, on the one hand, to the soil the calcareous principle which it does not contain, and which is necessary to develope its full action on the atmosphere; and, on the other hand, to vegetables, the quantity which they require of this principle for their framework and their intimate constitution. It

* The two classes of manures which are described generally above, are conveniently designated in French each by a single word. "*Engrais,*" which we can only translate as manure, is limited in signification to such substances as directly enrich soils and feed growing plants—and "*amendemens,*" signifying substances which alter and improve the constitution, texture, and indirectly, the fertility of soil, but the operation of which is not to furnish food to plants. In speaking of the *action* of these different classes, the sense may be rendered, though not very precisely, by the words "enrich" and "improve;" but there is no one English term that will convey the meaning of either class of substances. "Alimentary manures" will be used for the first class, and "manures improving the constitution of soil," or some similar awkward, but descriptive phrase, can only render the meaning of the word "amendemens," unless "improvers" could be tolerated as a substitute for convenience. Tr.

would then be a better definition than that above, to say, that to *improve* the soil is to give to it the principles which it requires, and does not contain.

Importance of Manures which improve the Constitution of Soils.

The question of improving manure is of great interest to agriculture. This means of meliorating the soil is too little known, and above all, too little practised in a great part of France; and yet it is a condition absolutely necessary to the agricultural prosperity of a country. In the neighborhood of great cities, alimentary manures being furnished on good terms may well vivify the soil; but animal manures can suffice only in a few situations, and those of small extent; and in every country where tillage is highly prosperous, improving manures are in use. The Department of the North (of France) Belgium, and England owe to them, in a great measure, their prosperity. The Department of the North (which is, of all Europe, the country where agriculture is best practised and the most productive,) spends every year, upon two-thirds of its soil, a million of francs in lime, marl, ashes of peat and of bituminous coal [*houille**], and it is principally to these agents, and not to the quality of the soil, that the superiority of its production is owing. The best of its soil makes part of the same basin, is of the same formation and same quality, as a great part of Artois and Picardy, of which the products are scarcely equal to half the rate of the North. Neither is it the quantity of meadow land which causes its superiority; *that* makes but the fifth part of its extent, and Lille, the best *Arrondissement*, has scarcely a twentieth of its surface in meadow, while Avesne, the worst of all, has one-third. Nor can any great additional value be attributed to artificial meadows, since they are not met with except in the twenty-sixth part of the whole space. Neither can this honor be due to the suppression of naked fallows, since, in this country of pattern husbandry, they yet take up one-sixth of the ploughed land every year. Finally, the Flemings have but one head of large cattle for every two hectares† of land, a proportion exceeded in a great part of France. Their great products then are due to their excellent economy and use of manures, to the assiduous labor of the farmers, to courses of crops well arranged, but, above all, we think, to the improvers of soil, which they join to their alimentary manures. Two thirds of their land receive these regularly; and it is to the reciprocal action of these agents of melioration, that appears to be due the uninterrupted succession of fecundity which astonishes all those who are not accustomed continually to see the products of this region.

At this moment, upon all points in France, agriculture, after the example of the other arts of industry, is bringing forth improvements; in all parts especially, cultivators are trying, or wishing to try, lime, marl, ashes, animal charcoal. It is this particular point in progress, above all, for which light is wanting; and this opinion has induced the preparation of this publication. For more than thirty years the author has devoted himself, from inclination, to agriculture; but he has been especially attentive to calcareous manures. He has studied in the practice of much extent of country, in that of his own particularly, in personal experiments, and in what has been written on them, both by foreigners and countrymen. An *Essay on Marl* has been the first fruit of his labors, an *Essay on the use of Lime* will soon be ready: it is with these materials that he now sets himself to work. To prepare for this object, a series of articles, of the nature of a recapitulation rather than of a regular work, it was necessary to be concise, and yet not to omit any thing essential. It is proper, then, that he should limit himself to the prominent parts of his subject, those especially useful to practice. His advice will then be as often empirical as regular, and his directions will be precise, although supported by a few developements.

An extract from this work has appeared in the *Encyclopedie Agricole:* here it will again appear, but in the form of separate articles, which will be corrected by a general systematic view of the theory, founded on practice. This is the moment for multiplying publications on this subject, because in almost all parts of France it is the point in agriculture most controverted; that which induces the most labor and the greatest expenditure; which presents most doubts; and which has consequently most need of being made clear.

We shall not here enlarge upon the manner in which improving manures act: we will put off this important question, with its developements, to the article on lime. Here we only present the theory. Hereafter, that which we will hazard will be founded upon facts, and yet we do not promise these developements, except so far as may be necessary for the purpose of enlightening and directing practice.

* Statistique du department du Nord.

† The hectare is very nearly equal to two and a half English (or American) acres. Tr.

Of the various kinds of Improving Manures.

The first in order, and the most important, are calcareous manures. We comprehend under this name, lime, marl, old plastering mortar, and other rubbish of demolished buildings, beds of fossil shells [*falun*],* or shelly substances, plaster or gypsum: experience and reason will prove that we ought to arrange in the same class, and by the side of the others, wood ashes, ground bones, and burnt bones. We will not place in the same list the ashes of peat, of bituminous coal, and red pyritous ashes: their effect is not owing to their lime, but (as will be seen afterwards) rather to the effect of fire upon the earthy parts, and particularly upon the argil which they contain.

We shall next in order treat of manures of the sea, or saline manure of different kinds, of mixtures of earth, of calcined clay: and finally, of paring and burning turf, and the different questions which peat presents in agriculture.

Of Liming—On the Use of Lime for the Improvement of Soil.

1. Among the immense variety of substances, and of combinations which compose the upper layers of the globe, the earthy substances, silex, alumine, and lime, form almost exclusively the surface soil: the greater portion of other substances being unfit to aid vegetation, they ought to be very rare upon a surface where the Supreme Author willed to call forth and to preserve the millions of species of beings of all kinds, which were to live on its products.

It was also a great benefit to man, whose intelligence was to be exercised upon the surface of the soil, to have so few in number the substances proper to support vegetation. The art of agriculture, already so complex, which receives from so many circumstances such divers modifications, if there had been added new elements much more complicated, would have been above the reach of human intelligence.

2. But among these substances, the two first, silex and alumine, form almost exclusively three-fourths of all soils; the third, the carbonate of lime, is found more or less mixed in the other fourth: all soils in which the latter earth is found, have similar characters, producing certain families of vegetables, which cannot succeed in those in which it is not contained.

The calcareous element seems to be in the soil a means and a principle of friability. Soils which contain calcareous earth in suitable proportions, suffer but little from moisture, and let pass easily, to the lower beds, the superabundance of water, and consequently drain themselves with facility. Grain and leguminous crops, the oleaginous plants, and the greater part of the vegetables of commerce, succeed well on these soils.

It is among these soils that almost all good lands are found. Nevertheless, the abundance of the calcareous principle is more often injurious than useful. Thus it is among soils composed principally of carbonate of lime that we meet with the most arid and barren, as Lousy Champagne, part of Yonne, and some parts of Berry.

3. The analysis of the best soils has shown that they rarely contain beyond ten per cent. of carbonate of lime; and those of the highest grade of quality seem to contain but from 3 to 5 per cent. Thus the analysis of Messrs. Berthier and Drapiez show 3 per cent. of it in the celebrated soil of the environs of Lille.

4. But all these properties, all these advantages, all these products, calcareous manures bear with them to the soils which do not contain the calcareous principle. It is sufficient to spread them in very small proportions: a quantity of lime, which does not exceed the thousandth part of the tilled surface layer of the soil, a like proportion of drawn ashes, or a two-hundredth part (or even less) of marl, are sufficient to modify the nature, change the products, and increase by one-half the crops of a soil destitute of the calcareous principle. This principle, then, is necessary to be furnished to those soils which do not contain it; it is then a kind of condiment disposed by nature to ameliorate poor soils, and to give to them fertility.

Ancient Date of the Use of Lime.

5. Lime, as it appears, has long ago been used in many countries. However, nothing proves that its effect was well known to the Greeks and Romans, the then civilized portion of mankind. Their old agricultural writers do not speak of the use of lime on cultivated lands, nor on meadows. Pliny, the naturalist, tells us, however, that it was in use for vines, for olives, and for cherry trees, the fruit of which it made more forward: and he speaks of its being used on the soil generally

* "*Falun.* Beds formed by shells. There is one of these immense beds in Touraine. The cultivators of that country use this shelly earth to improve their fields." This definition is from Rozier's *Cours Complet*, and though it clearly shows that the substance in question is the same as what is called "marl" in Virginia, it is equally clear that neither of these authors consider *falun* as being *marl*. Tr.

in two provinces of Gaul, those of the Pictones and Ædui,* whose fields lime rendered more fruitful. The agriculture of the barbarians was then, in this particular, more advanced than that of the Romans. After that, all trace of the use of lime in agriculture is lost for a long time—whether because it had ceased to be used, or only because the notice of it was omitted by writers on agriculture. The trace is again recovered with Bernard Pellissy, who recommends the use of it in compost in moist lands, and speaks of his use of it in the Ardennes. Nearly a century later, Olivier de Serres† advises its employment in the same manner, and reports that they made use of it in the provinces of Gueldres and Juliers [in Belgium]. He makes no mention of its use in France: but as the practices of agriculture were not then much brought together, and were but little known, it may be believed that at that time Flanders, Belgium, and Normandy, made use of lime.

In England, liming seems to have been in use earlier and more generally than in France. but then, and ever since, good agricultural practices have remained in the particular countries where they were established, without being spread abroad. Now, novelties carry no alarm with them—and within the last twenty years liming has made more progress than in the two preceding centuries.

Of Soils suitable for Liming.

6. Lime, as has been said before, suits such soils as do not contain it already. To distinguish these soils from others, chemical analysis is, without doubt, the surest means; but it offers often too many difficulties, and lime may be met with in a soil in proportion great enough to exert its power on vegetation without producing effervescence with acids.‡ But visible characters may furnish indications almost certain. The soils where the cow wheat, [*melampyre,*] rest-harrow, [*l'ononis, ou arrete-bœuf,*] thistles, colt's foot, [*tussilage,*] and red poppy, spring spontaneously—which produce well in wheat, legumes, (or plants of the pea kind,) and especially sainfoin—where the chestnut succeeds badly—which shows but little of dog's-tooth, [*chiendent,*] volunteer grasses, or common weeds, [*gramines adventices*] except of the small leguminous kinds—soils which, after being dry, crumble with the first rain—all these are almost certainly calcareous, have no need of lime, nor its compounds,* and would feel from their use rather ill than good effects.

On the contrary, all soils composed of the moulderings [*debris*] of granite or schistus, almost all sandy soils; those which are moist and cold of the immense argilo-silicious table lands [*plateaux argilo-silicieux*] which separate the basins of great rivers;† those where rushes, [*petit ajonc*] the heath, *les petits carex blancs*, the whitish moss spring spontaneously—almost all the soils infested with *avoine a chapelets*, with dog's-tooth, with bent grass, [*agrestis,*] red sorrel, and the little feverfew—that soil where, unless so clayey as to offer great difficulty to cultivation, only rye, potatoes, and buckwheat, can be made to grow, and where sainfoin and the greater part of the crops of commerce cannot succeed—where, however, trees of all descriptions, and especially of the resinous kinds, the wood-pine, the sea pine, the larch, the northern pine, and the chestnut, thrive better than in the best land—all these soils are without the calcareous principle, and all the improving manures in which it is found, would give to

* *Ædui et Pictones calce uberrimos fecere agros.*

† Who wrote on Agriculture in the reign of Henry IV. of France. Tr.

‡ This is a full though indirect admission of the truth of the doctrine of *neutral soils*, maintained in the Essay on Calcareous Manures. Tr.

* Though both the truth and the usefulness of this passage, in general, are admitted, yet it is incorrect in the position that none of the "compounds of lime" would be advantageously employed on calcareous soils. On the contrary, the sulphate of lime (gypsum), the most important compound as a manure next to the carbonate, is most effective where the land has lime in some other form: and indeed, (as has been maintained elsewhere,) it seems generally inert and useless on soils very deficient in lime. [Essay on Calcareous Manures, pp. 50, 92.]

† The character of the lands called by the author "*plateaux argilo-silicieux*," and which he refers to frequently in the course of his essay, can only be gathered from the context. They are poor, intractable under tillage, and but little pervious to water. The name indicates their composition to be siliceous and aluminous earth almost entirely. It may be inferred that such lands resemble in soil the elevated level *ridges*, which in lower Virginia separate different water courses, and especially those which, in addition to being miserably poor, are remarkably close, stiff, and "water-holding," and are in some places called "cold livery land," "pipe-clay," or "cray-fish" soils. Soil of this kind, and of the most marked character, is particularly described at page 40, Essay on Calcareous Manures, 2d ed. M. Puvis elsewhere speaks of this argilo-silicieux" soil as being found every where in France, and as known in different places under the various names of "terrain blanc," "blanche terre," in the south, "boulbenne," in the north, of "terre clytre," and "terre a bois"—and the basin of the Loire, "terre de Sologne." The last name would direct us to the lands of Sologne, which furnish it, as it may be presumed, as being of like quality. Arthur Young says, "Sologne is one of the poorest and most unimproved provinces of the kingdom, and one of the most singular countries I have seen. It is flat, consisting of a poor sand or gravel, everywhere on a clay or marl bottom, retentive of water to such a degree that every ditch and hole was full of it." Tr.

these the qualities of, and nourish the growths peculiar to, calcareous soils.

But there, more than elsewhere, it is especially necessary to avoid too much haste. Liming upon a large scale ought not to be done, until after having succeeded in small experiments on many different parts of the ground designed to be improved.

Extent of Surface to which Lime is suitable.

7. A great proportion of the soil of France does not contain the calcareous principle. The country of primitive formation—the mountains of which the rock is not calcareous—many soils even, of which the subsoils inclose calcareous formations—the great and last alluvion which has covered the surface, and which still composes it wherever the return waters have not carried it off with them—also extensive surfaces, in the composition of which the calcareous principle had not entered except in small proportions, and which small amount has been worn out by the successions of vegetation—all these kinds of soil, which comprise at least three-fourths of the surface of France, to be fertilized, demand calcareous manures. If it is admitted that one-third of all this space has already received aid from lime, marl, ashes of wood, or of peat, of bones burnt, or pounded, there will still remain the half of France to be improved by such means; an immense task, doubtless—but of which the results will be still more prodigious, since it will cause the products of all this great space to be increased one-half, or more.

Of the various Modes of applying Lime to the Soil.

8. Three principal modes of proceeding are in use for applying lime. The first is the most simple, and is the most general wherever lime is obtained cheaply, and where culture is but little advanced in perfection, and manual labor is dear. This consists in putting the lime [the burned limestone] immediately on the ground in little heaps at 20 feet average distance, and each heap containing, according to the rate of limiting, from a cubic foot of the stone to half that quantity. When the lime has been slaked by exposure to the air, and has fallen into powder, it is spread on the surface so as to be equally divided.

9. The second mode differs from the first in this respect: the heaps of stone are covered with a coat of earth, about six inches thick, according to the size of the heap, and which is equal to five or six times the bulk of the lime. When the lime begins to swell, by slaking, the cracks and openings in the heap are filled with earth: and when the lime is reduced to powder, each heap is worked over, so as to mix thoroughly the lime and the earth. If nothing hurries the labor, this last operation is repeated at the end of fifteen days—and then, after waiting two weeks more, the mixture is spread over the soil.

10. The third process, which is adopted where culture is more perfect, where lime is dear, and which combines all the advantages of liming without offering any of their inconveniences, consists in making compost heaps of lime and earth, or mould. For this, there is first made a bed of earth, mould, or turf, of a foot, or thereabouts, in thickness. The clods are chopped down, and there is spread over a layer of unslaked lime of a hectolitre* for the 20 cubic feet, or a ton to the 45 cubic feet of earth. Upon this lime there is placed another layer of earth, equal in thickness to the first, then a second layer of lime; and then the heap is finished by a third layer of earth. If the earth is moist, and the lime recently burned, 8 or 10 days will suffice to slake it completely. Then the heap is cut down and well mixed—and this operation is repeated afterwards before using the manure, which is delayed as long as possible, because the power of the effect on the soil is increased with the age of the compost; and especially if it has been made with the earth containing much vegetable mould. This method is the one most used in Belgium and Flanders: it is becoming almost the exclusive practice in Normandy: it is the only practice, and followed with the greatest success, in La Sarthe. Lime in compost is never injurious to the soil. It carries with it the surplus of alimentary manure which the surplus of product demands for its sustenance. Light soils, sandy or gravelly, are not tired by repetitions of this compost. No country, nor author, charges lime, used in this state, with having been injurious to the soil. In short, this means seems to us the most sure, the most useful, and the least expensive mode of applying lime as manure.

11. The reduction of burnt lime to powder by means of a momentary immersion in water in handle-baskets, serves much to hasten the slaking, whether the lime is to be applied immediately to the soil, or in compost heaps—some hours in this manner sufficing, in place of waiting two weeks; however, the

* The hectolitre contains 6102.8 English cubic inches, or is equal to 2.82, (or about 2.6-7) Winchester bushels. Therefore the hectolitre is rather more in proportion to the hectare, than our bushel is to the acre. The decalitre (named next page) is the tenth of a hectolitre, and of course the "double decalitre" is the fifth. Tr.

effect of lime, in this state, may well be different, as we have then the hydrate of lime, and less of the carbonate of caustic lime.* If great rains follow, this process is not without its inconveniences, because then the lime, which is already saturated with water, is more easily brought to the state of mortar, which ought to be avoided more than every other injury to the manure.

The reduction of burnt limestone to powder, whether it be spontaneous or by immersion, produces in the compost a bulk greater by one-half or more than that of the stone—10 cubic feet, producing 15—or a ton, 10 cubic feet. This increase is not uniform with all kinds of lime ; it is greater with the rich [*grasses*], and less with the poor varieties.

Liming, as practised in different Countries. In the Department of Ain.

12. The application of lime in Ain dates fifty years back. At the present time, the soil which has been limed is still more productive than the neighboring, not limed. Nevertheless, liming is but beginning to extend, while marling, which was begun fifteen years later, has already covered many thousands of hectares. This is because marling is an operation within the means of poor cultivators, being accomplished by labor alone ; while liming requires considerable advances, especially in this country, where lime is dear, and the dose given is heavy.

The dressings vary in quantity, from 60 to 100 hectolitres the hectare, according to the nature of the ground, and often according to the caprice of the cultivators. Although these limings have not been made with all the care and economy that was desirable, they have been very efficacious when the soil has been sufficiently drained. The following tables, extracted from the registers of three contiguous domains, belonging to M. Armand, three years before, and nine years during the progress of liming, give us the means of appreciating the results. The quantities of seed and of crops, are calculated in double decalitres, or in measures of fifths of hectolitres.

* An incorrect expression, certainly, but literally translated. Tr.

Table of product of the domain of La Croisette.

YEARS.	RYE.		WHEAT.	
	Seed.	Product.	Seed.	Product.
1822	110	600	24	146
1823	110	764	24	136
1824	110	744	24	156
1825	107	406	27	251
1826	106	576	28	210
1827	100	504	30	249
1828	90	634	36	391
1829	82	538	48	309
1830	60	307	60	459
1831	78	350	40	417
1832	55	478	68	816
1833	61	529	52	545

Table of product of the domain of Misериat.

YEARS.	RYE.		WHEAT.	
	Seed.	Product.	Seed.	Product.
1822	120	487	16	100
1823	120	708	16	103
1824	120	644	18	84
1825	112	504	28	228
1826	120	677	20	115
1827	115	594	20	162
1828	118	726	40	328
1829	104	566	41	277
1830	79	298	71	477
1831	91	416	43	326
1832	79	411	75	786
1833	76	616	48	351

Table of product of the domain of La Baronne.

YEARS.	RYE.		WHEAT.	
	Seed.	Product.	Seed.	Product.
1822	110	505	22	180
1823	110	643	22	138
1824	110	662	24	149
1825	102	398	32	252
1826	110	612	32	187
1827	107	546	34	204
1828	98	696	38	343
1829	84	608	40	268
1830	91	389	59	374
1831	92	411	40	295
1832	70	512	80	649
1833	75	511	51	471

The application of 3000 hectolitres [8,490 bushels] of lime, of the value of 6000 francs [$1116] upon 32 hectares [80 acres] of ground, made successively during nine years, has then more than doubled the crops of winter grain, the seed being deducted. The other crops of the farms have received a proportional increase; and the revenue of the proprietor, in doubling, has annually increased two-thirds more than the amount of the sum expended in the purchase of lime. Still, there is not yet half the arable land limed, since of 66 hectares, only 32 have received this improvement.

The products of 1834 are still greater than those of 1833. But these are sufficient to prove the importance and utility of applying lime to suitable soils.

Many other examples sustain these results; and from them all it appears, that the wheat seedings are increased from double to triple—that the rye lands, from bringing four to five [to one of seed] in rye, are able to bring six to eight in wheat—and that other products are increased in proportion. The melioration then is, relatively, much greater upon bad ground than upon good, since it is two-thirds and more on the wheat land, and on the rye lands the crop is increased in value three-fold.

Flemish Liming.

13. The use of calcareous manures in the department of the North, as in Belgium, appears to be as old as good farming. It is now much less frequent in Belgium. The ancient and repeated limings have, as it seems, furnished to great part of the soil all that is necessary to it, for the present. But the department of the North still receives lime, marl, or ashes, every where, or nearly so, where lime is not a component ingredient of the soil. They distinguish in this country two kinds of liming. The first [*chaulage foncier*] consists in giving to the soil, every 10 or 12 years before seed time, four cubic metres, or 40 hectolitres of lime to the hectare.* They often mix with the slaked lime, ashes of bituminous coal, or of peat, which enter into the mixture in the proportion of from a third to a half, and take the place of an equal quantity of lime. The other mode of liming [*chaulage d'assolement*], is given in compost, and at every renewal of the rotation, or upon the crop of spring grain. It is also in regular use in this country, still more than in Belgium, upon the meadows on cold pasture lands, which do not receive the waters of irrigation. It warms the ground and increases and improves its products. The older the compost is, the greater its effect, which lasts from 15 to 20 years, at the end of which time the dressing is renewed.

14. The limings of Normandy, the most ancient of France, are kept up in the neighborhood of Bayeux, while elsewhere they are forbidden in the leases: however, now they go over all the surface which has need of them; but in place of being applied immediately to the soil, as in the ancient method, the lime is almost always put in compost.

Liming of La Sarthe.

15. Of the modes of using lime, that of La Sarthe seems preferable. It is at once economical and productive, and secures the soil from all exhaustion. It is given every three years, at each renewal of the rotation, in the average quantity of 10 hectolitres to the hectare,* in compost made in advance, with seven or eight parts of mould, or of good earth, to one of lime. They use this compost on the land for the autumn sowing, and placed alternately with rows of farmyard manure. This method, of which the success is greater from day to day, is extending on the great body of flat argilo-silicious lands, which border the Loire; and it would seem that this method ought to be adopted every where, on open soils that permit surplus water to drain off easily.—On very moist soils the dose of lime ought perhaps to be increased.

We would desire much to inculcate with force the suitableness, and eminent advantages, of using at the same time lime and [alimentary] manure. Here they do better still, in using at the same time a compost of lime with earth and dung. In addition, during the half century that the Manceaux have been liming, the productiveness of the soil has not ceased to increase.

16. The countries of which we have spoken, are those of France in which liming is most general. However, more than half the departments, I think, have commenced the use, and in a sixth, or nearly, it seems to be established. Doubtless, the first trials do not succeed every where. There is required a rare combination of conditions for new experiments, even when they have succeeded, to induce their imitation by the great mass. Still, successful results are multiplied, and become the centres of impulse, from which meliorations extend.

* 46 bushels to the acre, English or American measure. Tr.

* 11¼ bushels to the acre. Tr.

English Liming.

17. The English limings seem to be established upon quite another principle from that of France. They are given with such prodigality, that the melioration upon the limed soil has no need to be renewed afterwards. Whilst in France we are content to give from a thousandth to a hundredth of lime to the tillable soil, from 10 to 100 hectolitres to the hectare, they give in England from one to six hundredths, or from 100 to 600 hectolitres the hectare. The full success of the method of our country might make us regard the English method as an unnecessary waste. It seems that they sacrifice a capital five, six, ten times greater, without obtaining from it a result much superior; and that without lavishing [alimentary] manures also afterwards, the future value of the soil would be endangered in the hands of a greedy cultivator.

We will not urge the condemnation of a practice which seems to have resulted in few inconveniencies. The abundance of alimentary manures which the English farmer gives to his [limed] soils, has guarded against exhaustion: and then, in very moist ground, they have doubtless, by the very heavy liming, made the soil healthy, and its nature seems modified for a long time to come; and such kinds, and where *humus* abounds, will take up a heavy dose of lime, and, as it seems, always without inconvenient consequences; there is then formed there the *humate of lime* in the greatest proportion, and we shall see that this combination is a great means of productiveness in the soil.*

Surface Liming.

18. In Germany, where liming and marling, like most other agricultural improvements, have recently made great advances, besides the ordinary modes of application, lime is used as a surface dressing. They sprinkle over the rye, in the spring, a compost containing 8 to 10 hectolitres of lime to the hectare, fifteen days after having sown clover. Also on the clover of the preceding year, they apply lime in powder, which has been slaked in the water of a dunghill, the dose being less by one-half; the effect upon the clover and the following crop of wheat is very advantageous.

In Flanders, where they use lime mixed with ashes, it is especially applied to meadows, natural or artificial, and the application is then made on the surface.

Burning Lime.

19. The burning of lime is performed with wood, with pit coal, or with peat; in temporary kilns, or furnaces, in permanent, or in perpetual kilns. It is burned in many places most economically with coal, but it is not so good a manure as the lime burned with wood, because, as it seems, of the potash contained in the latter case. There are but few places in which peat is used for this purpose; however, in Prussia they succeed with three-fourths peat and one-fourth wood. It is, doubtless, a very economical process, and the *Société d'Encouragement* has given in its transactions plans of peat kilns; but I know not whether the operators who received prizes for their use have continued the practice.

Temporary kilns admit of the burning of a great quantity of lime; but the permanent kilns burn it with most economy of fuel. In the first, 5 quintals of wood burn 4 quintals, or 1 ton, or 2¼ hectolitres of lime—and in the others, the same quantity of wood will suffice for 6 quintals or 3½ hectolitres. But in the permanent kilns such is the expense of construction and repairs, that they cannot be justified except when kept in frequent use. Coal burns from three to four times its bulk of lime—the shape of the kiln, the kind of limestone, and that of the coal, making the difference. Hydraulic lime is calcined more easily than the common [*chaux grasses*]. Egg-shaped kilns for coal seem to be preferable to the conical, which are more generally met with.

Precautions to be used in Liming.

20. Whatever may be the method adopted for using lime, it is essential that, like all calcareous manures, it should be applied in powder, and not in a state like mortar—and upon the earth when not wet. Until the lime is covered up finally, all rain upon it ought to be avoided, which reduces it to paste or to clots: and this injures its effect greatly, and even more than reasoning can explain. It ought not to be placed except upon soil, the surface mould of which drains itself naturally [by permitting the water to pass through.] On a marshy soil, unless the upper layer has been well-dried, or in a very moist soil, from which the

* In this passage the author distinctly affirms the truth of the chemical combination in the soil of calcareous and vegetable (or other putrescent)—or the power of calcareous earth to fix and retain enriching matter—which is maintained in the *Essay on Calcareous manures*, (pp. 30, 31,) to be the most important action of calcareous matter as an ingredient of soil.—Still M. Puvis seems to attach much less importance to this than to other agencies of lime, which are considered in the Essay as of little value in comparison. Tr.

surface water does not sink or pass off easily, the properties of lime remain as it were locked up, and do not make themselves seen, until, by new operations, the vegetable mould has been drained and put in healthy condition.

On an argillaceous and very moist soil, the use of marl, which is applied in great quantities, is preferable to that of lime, because it can have a more powerful effect in giving the deficient health to the surface mould. On soil of this kind, a deep ploughing is a preliminary condition, essential to the success of either liming or marling: because in increasing the depth of the tilled soil, we increase also the means of putting the surface into healthy condition.

21. To secure the effect of lime on the first crop, it ought to be mixed with the soil some time before the sowing of the crop: however, if it is used in compost, it is sufficient that the compost be made a long time previously.

Lime, whether alone or in compost, spread dry upon the soil, ought to be covered by a very shallow first ploughing, preceded by a slight harrowing, in order that the lime, in the course of tillage, may remain always, as much as possible, placed in the midst of the vegetable mould.

Lime, reduced to the smallest particles, tends to sink into the soil. It glides between small particles of sand and of clay, and descends below the sphere of the nutrition of plants, and stops under the ploughed layer of soil: and when there in abundance, it forms by its combinations a kind of floor, which arrests the sinking water, and greatly injures the crops. This is an inconvenience of lime applied in heavy doses, and is hastened by deep ploughing.

Various qualities of Lime.

22. It is necessary for the farmer to know the nature of the lime which he uses. It may be pure, or mixed with silex, clay, or magnesia. *Pure lime* is the most economical, the most active, that which can produce the most effect in the least quantity.

Silicious limestone is used in greater quantity. The lime from it receives, as does the foregoing, the name of *hot lime*, and there is little difference in the application, except that more of the latter is wanting.

Argillaceous lime is the same as the hydraulic lime, or the *poor lime* of builders. It appears that the first two kinds are more favorable to forming grain, while the latter favors more the growth of straw, grasses, and leguminous crops. It is better for the improvement of the soil, but a heavier dose of it is required.

Magnesian lime acts very powerfully, but exhausts the soil if given in a large dose, or if it is not followed by alimentary manure in abundance. It has exhausted some districts in England, and entire provinces of America,* and it is to this kind that seem due most of the complaints made against lime.

By chemical processes the farmer may make himself sure of the nature of the lime which he uses.

Pure lime is commonly white, and is dissolved, without any thing being left, in nitric or muriatic acid.

Silicious lime is often gray, and leaves a sandy residue [after solution], which is rough to the touch.

Argillaceous lime is obtained from stones which have a clayey odor and appearance: it is commonly yellow; and leaves, after the solution, a residue which is mostly an impalpable powder [*et qui prend en masse*], which may be formed into a mass when wet.

Magnesian lime is made from stone commonly colored brown or pale yellow; it forms a white cloud in nitric acid, diluted with water, and used in less quantity than sufficient for saturation.

Of second Limings.

23. When the limed field returns to the state in which it was before the operation, when the same weeds re-appear, and the crops lower in product, it is time to renew the application of lime. It may be conceived that the time of the second liming depends on the amount given in the first. When the dressing has been light, it is necessary, as is done by the Flemings and the Manceaux, to recommence entirely, or to the extent of the first dressing: when it has been heavy, the next may be diminished by one-half. Besides, in this matter we should take counsel of the state of the soil and of experience, because there are some lands which demand, and can use heavier doses of lime than others.

Quantities applied.

24. The quantities of first as of second dressings of lime, vary with the consistence

* The author has been deceived by exaggerated accounts of injury from liming in America. It is probable that wherever it occurred, it was caused by the usual ignorance of the action of lime: from erroneously considering it as alimentary, and directly fertilizing manure, and after applying it, wearing out the soil by continued grain crops. Such effects are spoken of by Bordley. Tr.

of soils: they ought to be small on light and sandy soils—and may, without ill consequences, be heavy on clay soils.

The dose ought to vary according as the soil is more or less pervious to water, or as drained well or ill by its texture. Small applications to soils from which the superfluous water does not pass easily, are but little felt; but if the dressing is heavy, and the ploughing deep, the lime aids the draining and adds to the healthy state of the soil. It may be conceived that the quantity of lime ought also to be increased with the annual quantity of rain that falls—because in proportion to that quantity ought the openness of the soil, and its fitness for draining, to be extended.

Nevertheless, the practices of the departments of the North and of La Sarthe seem to indicate the average dressing which suits in general for land: thus the liming of the North, which every ten or twelve years gives to the soil 40 hectolitres of lime to the hectare, or a little more than three hectolitres a year, agrees with that of La Sarthe, which gives eight or ten hectolitres every three years. The first plan gives at one dressing what the other distributes in four: as both make a like average, it may be thence inferred that the earth demands annually three hectolitres, [323 bushels to the acre,] to sustain its fecundity. But as neither the soil nor the plants consume all this quantity of lime, it is to be believed, that at the end of a greater or less length of time, the soil will have received enough to have no more need of it for a certain space of time.

Manner of treating Limed Lands.

25. After having, by liming, given the soil a great productive power, having put it in condition to produce the most valuable crops, which are often also the most exhausting, it is necessary to husband these resources—to give manure in return for the products obtained—to employ as litter, and not as food, the straw, now increased by one half—to raise grass crops from the soil now fitted to bear them with advantage—in short, to modify the general plan, and the detail of the culture according to the new powers of the soil, the prices of commodities, and to local conveniences.

However, it is not necessary to hurry the change of the rotation. Such an operation is long, difficult, very expensive, and ought not to be executed but with much deliberation.

Effects of Lime on the Soil.

26. The effects of lime, although similar to, are not identical with, those produced by marl; and the qualities of soils limed, differ in some points from those of natural calcareous soils. The grain from limed land is rounder, firmer, gives less bran, and more flour, than that from marled land: the grain of marled land is more gray, gives more bran, and resembles that made upon clover, though it may be preferable to the latter. The grain of a limed soil is more like that from land improved with drawn ashes. Limed land is less exposed to danger from drought than marled land, on soils naturally calcareous. The crop is not subject to be lodged at flowering time, when the sowing was done in dry earth.

27. In limed earth, weeds and insects disappear. The earth, if too light, acquires stiffness, and is lightened if too clayey. The surface of the argilo-silicious soil, before close and whitish, is made friable, and becomes reddish, as if rotten: it hardens and splits with drought, and is dissolved by the rains which succeed. This spontaneous loosening of the soil facilitates greatly the labor of the cultivator, the movement of the roots of the growing plants, and the reciprocal action of the atmosphere upon the soil, which remains open to its influence.

All these new properties which the limed soil has acquired, doubtless explain in part the fertilizing means which calcareous agents bring to the soil: but we think it is still necessary to seek some of these causes elsewhere.

28. Lime, according to the recent discoveries of German chemists, seizes in the soil the soluble humus or humic acid, takes it from all other bases, and forms a compound but slightly soluble, which appears, under this form, eminently suitable to the wants of plants. But as this compound is not soluble in less than 2000 times it weight of water, while without the lime the humus is soluble in a volume of water less by one-half, it would follow that, in consequence of lime, the consumption of this substance, and the productive power of the soil would, in like proportion, be better preserved. Since the products of the soil increase much from the liming, while the humus is economised, since these products borrow very little from the soil, which remains more fertile while thus yielding greater products, it follows that the principal action of the lime consists, at first, in augmenting, in the soil and in the plants, the means of drawing from the atmosphere the vegetable principles which they find there; and next, in aiding, according to the need, the formation, in the soil or the plants, the substances which enter into the composition of plants, and which are not met with ready formed either in the atmosphere or in the soil.

The researches upon these various points are curious, important, interesting to practice as well as to science—and will lead us to explain, by means not yet appreciated, the action of lime upon vegetation.

Absorption by plants of the principles of the atmosphere, in the vegetation on uncultivated soils.

29. Saussure has concluded, from his experiments, that plants derive from the soil about one-twentieth of their substance; and the experiments of Van Helmont and of Boyle have proved that considerable vegetable products diminish very little the mass of the soil. But this fact is still better proved by the observation of what passes in uncultivated soils.

Woodland that is cut over in regular succession (*taillis*) produces almost indefinitely, without being exhausted, and even becoming richer, the mass of vegetable products which man gathers and removes, and of which the soil does not contain the principles. If, instead of woodlands thus partially and successively cut over, we consider upon the same soil a succession of forests, and, for greater ease of estimation, resinous forests, we find for the products of the generation of an age, forty to fifty thousand cubic feet to the hectare. This product is less than that of the resinous forests of many parts of the country, and yet it is nearly equal in bulk to half of the layer of the productive soil itself: it represents an annual increase of 24,000 weight of wood to the hectare—and which is produced not only without impoverishing, but even while enriching the soil, by an enormous quantity of droppings and remains of all kinds.

These products which do not come from the soil, are then drawn from the atmosphere, in which plants gather them by means of particular organs designed for that use. These organs are the myriads of leaves which large vegetables bear—aerial roots, which gather these principles either ready formed in the air, or which take up there the elements, to combine them by means of vegetable power. But these aerial roots exert quite a different and superior energy in gathering the constituent principles of plants in the atmosphere, to that of the roots in the ground—since the former furnish nearly the whole amount of the vegetable mass, while the latter draw but very little from the soil.

30. Plants may well find in the atmosphere the greater part of the *volatile* principles which compose them—the carbon, hydrogen, oxygen, and azote. But it is not so easily seen whence they obtain the *fixed* principles of which their ashes are composed. These products could not exist ready formed in the soil—for the saline principles contained in the ashes of a generation of great trees, which would amount to more than 25,000 weight to the hectare, would have rendered the soil absolutely barren, since, according to the experiments of M. Lecoq of Clermont, the twentieth part of this quantity is enough to make a soil sterile. We would find a similar result in accumulating the successive products of an acre of good meadow. It is then completely proved that the saline principles of plants do not exist ready formed in the soil. They are no more formed in the atmosphere, or the the analyses of chemists would have found them there. However, as the intimate composition of these substances is not yet perfectly known, their elements may exist in the atmosphere, or even in the soil, among the substances which compose them.

Neither can it be said that these salts may be derived from the atomic dust which floats in the air; for this dust is composed of fragments organic and inorganic, carried especially to the plants themselves, and then, in estimating this atomic matter at the most, we will scarcely find in it the hundredth part of the saline substances contained in the vegetable mass produced. We ought then to conclude that the saline substances of plants are formed by the powers of vegetation or of the soil.

31. In like manner as with the saline principles, the lime and the phosphates which are formed in ashes ought to be due to the same forces, whether the roots take up their unperceived elements in the soil, or the leaves gather them in the atmosphere. This consequence results evidently from this fact—that plants grown in soils, of which the analysis shows neither lime nor the phosphates, contain them notwithstanding in large proportion in their fixed principles—of which [or of the ashes] they often compose half the mass.*

Absorption of plants, in vegetation on cultivated soils.

32. Vegetation on uncultivated soils operates under conditions altogether different from those of the cultivated, so that the results receive modifications which it is important to examine.

Nature produces, and continues to produce, all the vegetable mass in spontaneous growth,

* This fact is explained very different by the Essay on Calcareous Manures (Ch. VII.) where it is used to sustain the doctrine of neutral soils.—[Tr.]

without any other condition than the alternation and succession of the species. In vegetation on cultivated land, by bringing together the same individual plants which are to grow abundantly on a soil and in a climate which, in most cases, are not those which nature had designed, there are required, besides the general condition of alternation of the species, frequent tillage of the soil, and means to repair its losses, that the culture may be productive and be continued. However, with these new conditions, the force of absorption of plants on the atmosphere still furnishes the greater part of the vegetable principles in soils not limed—and still more in limed soils.

To form a precise idea, we will take it in the land of the writer, its culture and its biennial rotation. As the same qualities of soil are found elsewhere, as no particular circumstance increases or impairs its products, there would be found similar results, for the same qualities of soil, with a different culture.—The inferences which we will draw from ours will apply then to all others.

On our soil of the third class, [or worst quality,] fallow returns every two years, with a biennial manuring of 120 quintals to the hectare. This mass contains more than four-fifths of water, which should not be counted as manure, and consequently the substance which serves for the reparation of the soil is reduced to 24 quintals. We reap, in rye, straw, and buckwheat, after the year of fallow, a dry weight of 40 to 50 quintals on an average. If it is supposed that all the manure is consumed, or employed in forming vegetable substance, still the soil would have furnished 18 to 20 quintals more than it received, and which excess would be due to the power of absorption, whether of the soil or of the plants, on the atmosphere.

On land of middle quality, which yields a crop every year, with a double manuring, that is to say, of 48 quintals of dry manure, in two years there is a product of wheat, maize, or potatoes, which amounts to from 12 to 15,000 weight, 120 to 150 quintals, of which two-thirds, or 80 quintals at least, are derived from absorption.

On soils of good quality, with a manuring of one-third more than the last, which is equal to 64 quintals of the dry substance to the hectare, there are obtained of dry products, in grain, straw, roots, or hay, double of the last, or nearly so, of which three-fourths, or 180 quintals, are due to the power of absorption.

Lastly—upon the most fertile soils, (*sols d'exception*,) where manures are useless, the product, often double, or at least half as much more than the last-mentioned, will amount to 360 quintals to the hectare in two years. This product would be, as in spontaneous vegetation, entirely due to absorption.

We would have, then, to represent the products of two years, in quintals, in the four classes of soil under consideration, the progressive amounts of 42, 130, 240, 360; or, by deducting from these products the weight of the manure, we would have, to represent the power of absorption, the progression 18, 82, 176, 360 quintals. From this is deduced, as the first conclusion, that, supposing the plants have consumed and annihilated all the substance of the manure given, (which is beyond the truth,) plants receive a much greater part of their substance from the atmosphere than from the soil; and that this power of drawing food from the atmosphere increases with the goodness of quality in soils.

33. The proportion of fixed substances, or ashes, in agricultural products, is 43 lbs. to the 1000, and consequently, in our four classes of land, the quantity amounts to 180, 559, 1032, 1548 pounds. But the soluble saline substances form at least half of these ashes: they are then produced in the two years of the rotation, in the quantities of 90, 279, 516, 774 pounds. But, according to Kirwan, barn yard manure yields 2 per cent. of soluble salts: then the manure given to these soils contained 48, 96 lbs. 128 of saline substances, which, being deducted from the preceding quantities, leave the four classes of soils stated 42, 183, 388, 774 lbs. of products in soluble salts, in two years of the rotation, gained solely by the absorbing forces of the soil and of plants.*

34. But, in the same soils, with the same manures and the same tillage, by the addition to the thickness of the ploughed layer of only one-thousandth part of lime, the products, whether volatile or fixed, are increased in a striking manner: the soil of the first-named (or lowest) quality reaches the product of the second—the second rises one-half or more—and that of the best (of the manured soils) increases a fourth. Thus, our scale of product becomes 130,200,300 quintals—and deducting the manure, 106,152,236 quintals, for the two years of the rotation. The most fertile soil (*sol d'exception*) cannot receive lime beneficially, because it contains it alrea-

* The proportions of ashes of different plants, and of their saline matters, vary greatly—and the uniform proportions assumed above, are far from correct, even as averages of unequal proportions. This will sufficiently appear from the following examples extracted from Saussure's table of the products of various vegetable substances. (See Davy's Ag. Chem. Lec. III.)

dy; these lands all belong to alluvions, where the calcareous principle has almost always been found in greater or less proportion.

35. The product of fixed principles [as ashes] in the three classes of limed soils, would be 559,868,1290 pounds, and in soluble salts 278,430,645 pounds; and, deducting the soluble salts of the manure, the quantities would be 230,334,525. A light addition of lime has then doubled the force of absorption, and almost tripled the quantity of saline principles produced. One of the most remarkable effects of lime consists then, in making a soil produce a much greater proportion of saline principles: and if the experiments of M. Lecoq upon the efficacy of saline substances on vegetation are to be admitted, it would be in part to the phenomenon of their production that lime would owe its fertilizing effect.

36. It results from what precedes, that salts are formed in the soil or in vegetables: thus we see every day the nitrates of potash and of lime form under our eyes in the soil, or elsewhere, without any thing indicating to us

Constituents of 100 parts of ashes.

Names of Plants.	Ashes from 1000 parts dry.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silicia.	Metallic Oxides.	Loss.
Wheat, in flower,	—	43,25	12,75	0,25	32	0,5	12,25
Do. seeds ripe,	—	11	15	0,25	54	1	18,75
Do. seeds ripe,	33	10	11,75	0,25	51	0,75	23
Straw of wheat,	43	22,5	6,2	1	61,5	1	78
Seeds of do.	13	47,16	44,5	——	0,5	0,25	7,6
Bran,	52	4,16	46,5	——	0,5	0,25	8,6
Plants of maize, (Indian corn,) a month before flowering,	122	69	5,75	0,25	7,5	0,25	17,25
Do. in flower,	81	69	16	0,25	7,5	0,25	17
Do. seed ripe,	46						
Stalks of do.	84	72,45	5	1	18	0,5	3,05
Spikes (tassels,) of do.	16						
Seeds of do.	10	62	36	——	1	0,12	0,88
Oats (entire plant),	31	1	24	——	60	0,25	14,75

The proportion of soluble salts, 2 per cent. found by Kirwan in barn-yard manure, however correctly ascertained in a particular case, can no more be relied on as a fixed and uniform proportion, or even a true general average, as used by M. Puvis in the estimates above. [Tr.]

the origin of the potash which is contained. But potash itself again forms spontaneously in drawn ashes, according to the observations of the chemist Gelhen. We see salts also renewed in the artificial nitre beds, with the aid of moisture and exposure to the air. But it is the presence of lime that determines this formation more particularly. The nitrates abound in the ruins of demolished edifices; they are formed in the walls, and in all parts of houses situated in damp places; they effloresce on the buildings of chalk in Champagne; they are produced spontaneously in the ploughed lands of the kingdom of Murcia. This effect, which we see that the calcareous principle produces every where, we think it produces in all the soils to which it is given, and where meet the circumstances which favour the formation of nitrates, viz: humidity, vegetable mould, and exposure to the air. But, according to the experiments of M. Lecoq and others, and the opinion which is established of the old agriculturists, the nitrates are the most fertilizing salts. It would be then to their formation, which it promotes in the soil, that lime owes, in part, its effect on vegetation.

37. The foregoing proofs of the daily formation in the soil, and by vegetable life, of saline and earthy compounds, taken in nature and on a great scale, are doubtless sufficient: but they may still be supported by the experiments and opinions of able men who have adopted the same system.

And first—in the experiment of Van Helmont, in five years, a willow of five pounds grew to weigh 169, and had caused a loss of only two ounces to the soil which bore it. But the 164 pounds which the willow had taken contained five pounds of ashes, which are due entirely to absorption, since the leaves and the other droppings of five years, which were not saved, would have given at least one pound of ashes, which makes up for, besides all that which, in spite of the sheet of lead which covered the top of the vessel in which the willow grew, it might have received in the waterings, and from other fortuitous circumstances. Boyle has repeated and confirmed this experiment in all its parts.

Lampadius, in different isolated compartments, some filled with alumine, others with silex, others with [carbonate of] lime, all pure, has made plants to grow, of which the burning has yielded to analysis like results; and which, consequently, contained earths which were not in the soils which bore them.

Saussure, in establishing that plants do not take in the soil more than a twentieth of their

substance, in extract of mould and in carbonic acid, has necessarily established, by the same means, that almost the whole amount of fixed principles do not proceed from the soil.

Braconnot has analyzed lichens, which contained more than half their weight of oxalate of lime—and he has observed others covered with crusts of carbonate of lime when there was none of this earth in the neighborhood.

Shrader, in burning plants grown in substances which did not contain any earthy principle, has found in their ashes, earths and salts which were neither in the seeds sown, nor in the pulverized matters in which the plants grew.

Lastly—the analyses of Saussure, though showing more of the carbonate of lime in the ashes of plants which grew on calcareous soils than on soils not calcareous, yet, nevertheless, they have formed more than a sixth of the ashes from vegetables on silicious soils—and Einhoff has found 65 per cent. of lime in the ashes of pines grown on silicious soil.* The labors of science then confirm what we have above established, that plants, or the soil, form salts and earths.†

* It is presumed, from the context, that these silicious soils were not the least calcareous.—[Ed. F. R.]

† Van Helmont's experiment, cited first in the list above, like M. Puvis' reasoning in general, furnishes ample proof that most of the volatile parts of vegetables, and the greater part of their bulk, are drawn from the atmosphere—and they are equally defective in proving that earths and other fixed principles are thence derived, or are formed by the power of vegetable life. Distilled water is not entirely free from earthy matter, and if it had been used for watering the willow, it would in five years have given some considerable part of the five pounds of solid matter in the ashes. But as we are not told that it was either distilled or rain water, it may be inferred that the comparatively impure water of a fountain or stream, was used for watering the plant, and which would more than suffice in so long a time to convey the whole increase of earthy and saline matter. The experiments of Lampadius and Shrader are liable to the same objection—and the former to this in addition—that his earths were deemed absolutely pure, when, in all probability, they were not so—and that a very slight admixture of other kinds with each, would furnish the minute quantity that a small plant could take up during its short and feeble existence under the circumstances stated. The results stated of the experiments of Braconnot, Saussure, and Einhoff, may be, and probably are, entirely correct—but they are fully explained by the doctrine of neutral soils, and need no support from, and give none to, our author's doctrine of the formation of lime by vegetable power.

But though deeming M. Puvis altogether wrong in this, his main and most labored position, and that the proofs cited above, as well as some others in the preceding section, are of no worth, still these pages which present his theory, contain what is of more value. He places in a strong point of view the important truth that the atmosphere is the great treasury of nature, from which nature doubles and tribles the amount of all the small portions given to the earth by the industry of man. The author's scale of actual products from different grades of soil is also interesting. It sustains the position assumed in the Essay on Calcareous Manures, that the worst soils are limed (or made calcareous) to most profit—and that alimentary manures, when needed, are most productive on the best soils.—[Ed. Far. Reg.

38. The fertilizing effect of fallow, or ploughing, of moving and working the soils, prove still more that all these circumstances determine the formation of fertilizing principles, and probably of saline principles, in all the parts of the soil which receive the atmospheric influences.

But salts are also formed in plants. The nitrate of potash, which takes the place of sugar in the beet—the oxalate of potash, so abundant in sorrel—the carbonate of potash in fern, in the tops of potatoes, and in almost all vegetables in the first period of their life—the sulphate of potash in tobacco—the nitrate of potash in turnsole and in pellitory—prove, without reply, that vegetation forms salts, as it forms the proper juices of plants, since the soil contains the one kind no more than the other. But can we say where plants take the elements necessary for all these formations? They can take them only in the soil by means of their roots, or in the atmosphere—in the soil, which would itself take them in the atmosphere, in proportion to the consumption of plants—or directly in the atmosphere by means of their leaves, which would there gather these elements. And if the analyses of the soils, and of the atmosphere, show almost none of these elements, it will be necessary to conclude from it that the substances which analysis has found there, are themselves, or would furnish if decomposed, the elements of the saline substances, although science may not yet have taught us the means of reaching that end.

39. The formation of lime, like that of the saline principles necessary to plants, is an operation which employs all the forces of vegetation—and these forces, directed to this formation, have no energy left to give a great developement to plants: but when the vegetable finds the calcareous principles already formed in the soil, it makes use of them, and preserves all its forces to increase its own vigor and size.

It would then result, from all that has been said, that lime modifies the texture of the soil—makes it more friable—invigorates it—renders it more permeable—gives it the power to better resist moisture as well as dryness—that it produces in the soil the humate of lime which encloses a powerful means of fertility—that lime increases much the energy of the soil and of plants to draw from the atmosphere the volatile substances of which plants

are composed, oxygen, hydrogen, carbon, and azote—that the limed soil in furnishing to plants the lime which they need, relieves the soil and plants from employing their powers to produce it—and finally, that lime promotes the formation of fixed substances, earthy or saline, necessary to vegetables. All this whole of reciprocal action and reaction of lime, on the soil, plants, and atmo sphere, explains in a plausible manner its fertilizing properties. We would, consequently, have nearly arrived at the resolving of an important agricultural problem, upon which were accumulated all these doubts.

The amount of lime taken up by vegetation.

40. The ashes of plants from calcareous soils, or those which have been made so by manures, contain 30 per cent. of the carbonate and phosphate of lime, which, by taking off the crop, is lost to the soil. But the product of limed land of middle quality, is during the two years of the course of crops, about 20,000lbs. of dry products to the hectare, which contain a little less than a hectolitre of lime in the calcareous compounds of the ashes. The vegetation has then used half a hectolitre a year. But we have shown that there was necessary, on an average, three hectolitres per hectare each year. Vegetation then does not take up, in nature, but a sixth of the lime which is given profitably to the soil; the other five-sixths are lost, are carried away by the water, descend to the lower beds of earth, are combined, or serve to form other compounds, perhaps even the saline compounds, of which we have seen that lime so powerfully favors the formation. Another portion, also, without doubt, remains in the soil, and serves to form this reserve, which in the end dispenses, for many years, with the repetition of liming.

Of the exhaustion of the soil by liming.

41. "Lime," it is said, "only enriches the old men: or it enriches fathers and ruins sons." This is indeed what experience proves, when, on light soils, limed heavily, or without composts coming between, successive grain crops have been made without rest, without alternations of grass crops, or without giving to the soil alimentary manures in suitable proportion. It is also what has happened when magnesia, mixed with lime, has carried to the soil its exhausting stimulus. But when lime has been used in moderation—when, without overburdening the land with exhausting crops, they have been alternated with green crops—and when manure has been given in proportion to the products taken off—the prudent cultivator then sees continue the new fecundity which the lime has brought, without the soil showing any sign of exhaustion. No where has there been complaint made of argillaceous soils being damaged by lime; and the productiveness of light soils is sustained in every case that the lime was used in compost.

In America, where the lime of oyster shells has taken the place of that of magnesian limestone, the complaints of the exhausting effects of lime have ceased.

*Healthiness given to the soil and to the country by calcareous agents.**

42. The unhealthiness of a country is not caused by the accumulation of water, nor from soil being covered by water. Places on the borders of water do not become sickly except when the water has quitted some part of the surface which it previously overflowed, and the summer's sun heats the uncovered soil, and causes the decomposition of the remains of all kinds of matter left by the water, and contained in the upper layers of the soil. Thus, ponds are not unhealthy except when drought, by lowering the waters, leaves extensive margins bare, to be acted on by the sun and air. In rainy years, fevers on the borders of ponds are rare.

Epidemic diseases most often arise on the borders of marshes laid dry—in the neighborhood of mud thrown out of ditches or pits—and in the course of bringing new land into cultivation, where the ploughed soil is for the first time exposed to the summer's sun. In the interior of Rome, the vineyards, the gardens are remarkably unhealthy—while the sickliness disappears where the emanations from the soil are prevented by buildings. In the Pontine marshes, they cover the dried parts with water to arrest the danger of their effluvia. It is then from the soil, and not from the waters at its surface, that insalubrious emana-

* There was no position in the Essay on Calcareous Manures which its author assumed with so much hesitation as the agency of those manures in removing causes of disease. That hesitation did not arise from doubt of the truth of the position—but because of its very high importance and its entire novelty—its being then sustained but by few known facts furnishing direct evidence, and by no known authority whatever of earlier writers. It is therefore the more gratifying to find in the work now presented, that about the same time, another and far remote investigator of the same subject, by a different course of reasoning, and by different proofs, had arrived at precisely the same conclusion—and that he maintains, even more generally than the former work, the important and sure effects of calcareous manures in rendering a country more healthy. [Tr.]

tions proceed. Waters placed on the surface, always in motion, agitated by every wind, are not altered in quality, and do not become unhealthy; but whenever they are contained in some place without power to receive exterior influences, or to have motion, they are altered in their odor, taste, and consequently injured in relation to health.

Whenever water then, without covering the soil, penetrates the upper layer without being able to run through the subsoil, it remains without motion, and stagnant, within the soil —is changed by the summer's sun, serves to hasten the putrefaction of the broken down vegetable remains in or on the mould, and the exhalations from the ground become unhealthy. Thus are all drained marshes, of which the surface only is dry, while the water still penetrates the subsoil—thus, all the margins of rivers which have been covered by recent inundations of summer, are unhealthy; thus also, (for a great and unhappy example,) the argilo-silicious plateaux, whenever the closeness of the subsoil does not let the water pass through, produce, in dry years, at the close of summer, emanations which attack the health of the inhabitants.

43. But this unhappy effect appears almost no where in calcareous regions: the margins of lakes and ponds there situated do not produce the same unhealthiness, and even the marshy grounds there are less unhealthy.

The waters which spring out of, or run over calcareous beds, are always healthy to drink. The borers of Artesian wells are anxious that the water which they obtain, to be good, may come out of the calcareous strata which they go through. When the waters which hold carbonate of lime in solution in carbonic acid* run over the surface, they give health to the meadows, in changing the nature and quantity of the products.

Linnæus thought that the unhealthiness of most countries depended on the nature of the water, and was owing to the argillaceous particles which they contain; now these argillaceous particles are always precipitated by the calcareous compounds. For this reason, the waters which stand upon, or run over marl or calcareous rock, are almost always limpid and clear, because the argillaceous particles have been precipitated by the effect of the solution in the water of the calcareous principle, which is itself dissolved by an excess of carbonic acid.

We are not far from believing then, that throwing rich marl, or limestone, into a well of muddy and brackish water, might have the effect, in part at least, of clearing it, and making it healthy to drink. This remedy, if it should not be as useful as we think, at least could not produce any injury.

Lime, in all its combinations, destroys the miasmata dangerous to life. Its chloride annihilates all bad odors, arrests putrefaction, and in short, has subjected the plague of Egypt to the skill and courage of Parisot. The white wash of lime upon infected buildings, upon the walls and mangers of stables, is regarded as serving to destroy the contagious miasmata of epidemic and epizootic diseases.

Lime destroys the plants of humid and marshy soils, and makes those suitable to better soils spring up: then its effect is to give healthiness or vigor to the soil, to dry it, and make it more mellow and permeable. The water then is no longer without motion, and altered consequently in its condition. The limed soil then, to the depth it is ploughed, ought to change the nature of its emanations as well as its products: and if the lower strata or subsoil, send up emanations, these effluvia, in passing through the improved layers of soil, where the calcareous agent is always at work and developing all its affinities, ought also to be modified, and take the character of those of the upper bed. The limed soil then, it would seem, ought to be made healthy.

But what we maintain here by induction, by reasoning, is fortunately a fact of extensive experience. Among all the countries in which lime has carried and established fertility, there is not cited, that I know of, a single one where intermittent fevers prevail— while they have never disappeared in a country even where an active culture draws good products from the impermeable argilo-silicious soil.

44. To extend the great benefit of healthiness to the whole of a country, it is no doubt necessary that the whole country should receive the health-giving agent. However, on every farm, in proportion as liming is extended over its surface, the chances of disease will be seen to diminish—and the healthiness of the country will keep pace with the progress of its fertility.

Result of the use of improving manures on the soil of France in general.

Three-fourths of the whole territory of France, to be rendered fruitful, have need

* As in limestone water, lime with the greatest proportion with which it can combine of carbonic acid, (forming super-carbonate of lime,) is soluble in water. The excess of acid is lost by heat, by exposure to air, &c., and then the lime is in form of carbonate—and being insoluble in water, falls separate to the bottom. [Tr.]

of calcareous agents. If the third of this extent has already received them, (which we believe is above the truth,) upon the other two-thirds, or the half of the whole, the agricultural products, by this operation, would be increased one-half or more, or one-fifth of the total amount. But agriculture, in enriching itself will increase its power, its capital, and its population; and will naturally carry its exuberant forces, its energy and activity to operate on the greater part of the 7,000,000 of hectares of land now [*en friche*] untilled, waste, and without product. By bringing these lands into cultivation and fertilizing them by liming, or by paring and burning the surface, they would be made to yield at least one-sixth of the total product. The gross product of the French soil, then increased by a third or more, might also give employment and sustenance to a population one-third greater than France now possesses; and this revolution due successively to the tillage of the soil, to annual improvements keeping pace with the progressive increase of crops, would be insensible. The state would grow in force, in vigor, in wealth, in an active and moral population, which would be devoted to peace, and to the country, because it would belong to this new and meliorated soil. And this great result would be owing simply to applying calcareous manures to the extent of the soils of France which require them!

46. Upon our extent of 54,000,000 of hectares, our population, increased to 44,000,000, would have for each, one hectare and a quarter, and would be less confined than the 24,000,000 of inhabitants of the English soil, who have only one hectare to the head; and yet our soil is at least as good, and it is more favored by climate. And then our neighbors consume in their food at least a fourth or fifth of meat, while only one-fifteenth of the food of our population consists of meat; and as there is required twelve or fifteen times the space to produce meat as bread, it follows that twice the extent of soil is necessary to support an Englishman as a Frenchman. Hence it results, that with an increase of one-third, our population would still have a large surplus product which would not exist in England, with an equal increase of population and equal increase of products of agriculture.

But this prosperity of the country, (yet far distant, but towards which, however, we will be advanced daily,) would be still much less than in the department of the North, where a hectare nearly supports two inhabitants. And yet they have more than a sixth of their soil in woods, marshes, or unproductive lands: they have, besides, another sixth, and of their best ground, in crops of commerce, which consume a great part of their manure, and which are exported almost entirely. This prodigious result is, without doubt, owing in part to a greater extent of good soil than is found elsewhere; but it is principally owing there, as well as in England, to the regular use of calcareous manures. As we have seen, more than two-thirds of this country [the North] belongs to the class of soils not calcareous, to the argilo-silicious plateaux, and makes use of lime, marl, or ashes of all kinds.

47. After this great result of increased productiveness, that upon health, although applied to the least extents of surface, would be most precious. Upon one-sixth of our country the population is sickly, subject to intermittent and often fatal fevers, and the deaths exceed in number the births. Well! upon this soil without marshes, calcareous manures would bring a growing population, more numerous than that of our now healthy parts of the country—and as labor would offer itself from every side, these regions, made healthy, would soon be those where the people would be most happy, the richest, and the most rapidly increasing in numbers.

48. If we are not under an illusion, the calcareous principle and its properties upon the soil, form the great compensation accorded by the Supreme Author to man, in condemning him to till the earth. Three-fourths of our soil, seem not to produce, except by force of pain and labor, the vegetables absolutely necessary for man. On all sides, and often beneath this surface so little favored, is found placed the substance necessary to the soil to render it as fertile as the best ground, to enable the cultivator to use for his profit the vegetable mould which it contains and has been accumulating for ages—and to cause the entire soil to be covered by a population active, moral, and well employed. And this precious condiment, this active principle of vegetation, is only needed to be applied in small proportions, to obtain products of which the first harvest often compensates for all the labor and expense. And to complete the benefit, insalubrity, which afflicts the infertile soil, disappears; the new population finds there at the same time strength, riches, and health. There, without doubt, is one of the most happy harmonies of the creation, one of the greatest blessings with which the Supreme Author has endowed the laborious man who is devoted to the cultivation of the earth.